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Title: Systemic Change, Open Data Ecosystem Performance Improvements, and Empirical Insights from Estonia: A Country-Level Action Research Study

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Abstract: The purpose of this paper is to provide an overview of how Estonia used action research and systems theory to improve the performance their Open Government Data (OGD) ecosystem. This paper understands performance of OGD ecosystems of as consisting of three parts: 1) OGD supply, 2) OGD usage, 3) communication, interaction, and linkages between OGD suppliers and users. It was believed that by taking a holistic approach, encouraging transparency and co-creation, and manipulating feedback loops it was possible to improve the performance of the ecosystem. The research uses and validates previous research on open government data ecosystems and by doing so also achieved increased levels of performance in Estonia's OGD ecosystem. The paper's main contributions are the creation of a framework based on systems theory, systems thinking, and action research for enacting strategic change in OGD ecosystems, conceptualizing feedback loops as a core part of OGD ecosystems, and the conceptualization of performance in OGD ecosystems. The paper concludes by offering nine core insights related to OGD ecosystems and their performance.

Key points:

- The paper brings forth a six-step framework for enacting strategic change within OGD ecosystems.
- Mental models are important, if the current mental models in government do not support the goal of the system, change is unlikely to occur.
- It is possible to take advantage of bottom-up initiatives to drive increased performance of OGD ecosystems by engaging in communication, transparency, and co-creation.
- By intervening at specific feedback points, it is possible to improve the performance of an OGD ecosystem.

Keywords: Systems Theory, Open Data, Open Data Ecosystem, Systems Thinking, Feedback Loops, System Performance, e-Government

Introduction

In the current academic debate, much attention has been devoted to studying and understanding Open Government Data (OGD) with a wide variety of methodologies, approaches, and focuses being adopted. Some studies focus on understanding the drivers and barriers to the use and release of OGD (Barry & Bannister 2014; Young & Yan 2017), some look at what can be done with OGD (Foulonneau et al., 2014; Khayyat & Bannister, 2017), while others take a more holistic and systemic approach to OGD, acknowledging that OGD is not just about specific technologies (Alexopoulos et al., 2014; Dawes et al., 2016; M. Najafabadi & Luna-Reyes, 2017). The research in this paper studies the Estonian (national) OGD ecosystem, falling into the latter camp, arguing that OGD is not just a technology, but part of a larger open system, co-evolving with its environment over time (McBride, 2020). Estonia is a country that is known around the world as a leader when it comes to digital government (Kalvet, 2012; Kitsing, 2011), but, when it comes to OGD, it is consistently labeled as a catching-up country with limited levels of performance (e.g. European Data Portal, 2018b; OECD, 2018a).

Performance is a subjective term: it does not have an objective existence, but, rather, it is a shared mental construct that is created through discussion between stakeholders involved in a given system (Brudan, 2010; Wholey, 1996). In a more system's specific view, all systems have a goal or function, they are supposed to do something (cars move you from A to B, air conditioning units keep a room cool, winter jackets keep you warm, etc…). The performance of these systems is related to how well they achieve that goal. What can be said about performance, then, is that it is a socially constructed phenomenon that is directly related to mutual agreement among stakeholders about the specific goal of a system. In the case of this paper, performance is related to the usage of OGD, supply of OGD, and interaction and communication about OGD amongst OGD users, OGD providers, and OGD beneficiaries, where higher levels would be associated with higher performance and lower levels would be associated with lower performance. While these measures of performance were defined within the Estonian OGD ecosystem context, they also mirror OGD performance measures discussed in the literature, such as by (Zuiderwijk & Janssen, 2014), who list three main performance measurements: usage of publicized data, risks of publicizing data, and benefits of publicizing data. Similarly, (Donker & Loenen, 2017) describe data supply, data governance, and user characteristics as performance measurements for OGD ecosystems. The performance of an OGD ecosystem is not just about the *availability* of OGD, but, rather, about the *usage* of OGD as it is only through its use that OGD is able to create public value (Janssen et al., 2012). Therefore, it follows that interventions in OGD ecosystems that boost the usage of OGD are likely to also lead to performance improvements.

Coming back to Estonia and its poor historical performance on OGD indices, previous research has identified why this is the case (e.g. McBride et al., 2018b). This participatory action research (Baskerville, 1999) started in 2018 and was conducted in an attempt to improve the poor performance of Estonia's OGD ecosystem. An opportunity for launching the action research initiative presented itself thanks to the decision of the Estonian Ministry of Economic Affairs and Communications to contract an external partner

to implement Estonia's OGD policy and improve the provision and usage of open data in Estonia. Open Knowledge Estonia, a non-profit community organization, won the three-year contract and engaged researchers from a local university in the work.

The starting point of the action research was the question "How to improve the performance of Estonia's OGD Ecosystem?" At the beginning stages of the research the researchers outlined and studied the main components, internal (systemic) and external (environmental), of the Estonian OGD ecosystem (this paper deals with OGD at the national level, the national OGD portal, and thereby also addresses primarily the national OGD ecosystem). Following this initial analysis, the researchers identified the drivers and barriers of OGD in Estonia, reusing and expanding on the findings of their prior work. The researchers also analyzed core weaknesses limiting the performance of the system. Building off of this knowledge, a widespread and systemic action-research-based approach has been conducted in cooperation between researchers, Open Knowledge Estonia, and government policymakers to make specific interventions with the intended purpose of improving the performance of Estonia's OGD ecosystem. This paper presents the findings of this research initiative based on the results obtained by the first half of 2020. By that time the Estonian OGD ecosystem had begun to show considerable performance improvements, evident from the results of external evaluations (international OGD indices), stakeholder feedback, and via concrete quantitative indicators.

Admittedly, action research is often written off as 'less scientific' due to its applied and context-specific nature (Davison et al., 2004). That being said, it is also generally well understood that action research is highly relevant, able to lead to development of new knowledge in ways traditional Newtonian science cannot (Susman & Evered, 1978) by "co-creating shared knowledge of the causal conditions of the social/behavioral world and its attendant difficulties" and, furthermore, that this new knowledge is theoretical in nature (Friedman & Rogers, 2009).

While this paper presents an overview of the transformation process of Estonia's OGD ecosystem and validates previous e-Government research on OGD ecosystems, its contributions are wider in scope than a case study or replicative research. The first, and major, contribution of this paper is its empirical demonstration at the country level of how a holistic and systemic approach to studying OGD ecosystems may be used to drive increased levels of performance via specific targeting and identification of feedback loops. Secondly, the paper develops and tests a framework for enacting systemic change in OGD ecosystems. This framework provides new theoretical knowledge that is likely to be of use for academics and the research community at large when it comes to studying OGD ecosystems, and, additionally, new practical knowledge that can be utilized by practitioners embarking on OGD ecosystem transformation projects. A third contribution is the conceptualization and further development of the concept of 'performance' when it comes to OGD ecosystems. A final contribution is the development, inclusion, and analysis of feedback loops as a specific systemic attribute within OGD ecosystems. Through these contributions, the paper and its results are likely to be of interest for any stakeholder working with OGD, specifically policy makers, academics, and NGOs who work directly with OGD are likely to find the results of this research to be beneficial.

In the following sections of the paper the research question is answered by, firstly, starting with an overview of its theoretical foundation. This foundation relies heavily on systems theory and system dynamics. Additionally, the OGD ecosystem model first proposed by (Dawes et al., 2016) that is adopted for this study of Estonia's OGD ecosystem is discussed. Following the presentation of the theoretical foundation, the participatory action research methodology is presented. After this initial discussion, the context related to OGD in Estonia, Estonia's OGD ecosystem, the identified weaknesses and performance problems, and the specific measures and changes made in an attempt to remedy the identified issues is described. Finally, the paper concludes by discussing the first results of these interventions and what changes in performance, positive or negative, in Estonia's OGD ecosystem have accompanied them. Additionally, the paper provides reflections on the used theory and highlights the main contributions of the research.

Theoretical Background

Epistemologically, this paper takes an alternative to the traditionally popular positivist approach in e-Government research and draws primarily from pragmatism. Pragmatism acknowledges that there are different ways to view the world, and that these views are never complete or completely accurate. When talking about pragmatism it has been noted that "pragmatism is concerned with action and change and the interplay between knowledge and action. This makes it appropriate as a basis for research approaches intervening into the world and not merely observing the world" (Goldkuhl 2012, p. 2). Theoretically, this research draws on concepts and ideas that are often associated with pragmatic studies: systems theory, systems thinking, systems science, and system dynamics. Systems theory is more holistic in nature, focusing on a system and its emergent behavior, the whole, rather than the parts within it. One of the most common approaches today that allows for systems theory to be applied is systems thinking. Systems thinking provides a way to approach and study systems, and, more specifically, acknowledges that "system structure is the source of system behavior" and furthermore that "structure is the key to understanding not just what is happening, but why" (Meadows 2008, p. 89). Additionally, the theoretical section of this paper presents an overview of OGD and OGD ecosystems. As OGD has often, but not always, been described or analyzed from an ecosystem-based perspective, it follows that a theoretical lens intended specifically for the study of such systems would be suitable. It is for this reason that the specific systems approach has been chosen for this research. By drawing on insights from the previous literature, this section outlines a six-step process that was used for the analysis of Estonia's OGD ecosystem.

Open Government Data

Whilst there is not yet a widely agreed upon definition for OGD, there are a number of key concepts that appear to be important to the definition, such as freely usable, licensed, government created/provided, and machine readable (McBride et al., 2018b). One common definition states that OGD is "non-privacy-restricted and non-confidential data which is produced with public money and is made available without any restrictions on its usage or distribution" (Janssen et al., 2012, p. 258). In contrast to this techno-centric

definition, the OECD notes that OGD is "a philosophy – and increasingly a set of policies – that promotes transparency and accountability and value creation by making government data available to all" (OECD, 2018). At this point, it is important to look at the name of 'OGD' itself, as "the name of a technology identifies what it means to the people who use it" (Nardi & O'Day, 1999). Interestingly, it appears that a normative value statement is being made here where 'opening' government data is viewed as inherently good. In line with this, Janssen et al., 2012 note that by opening up data the relationship between public sector and the public is changing, where citizens and other stakeholders are becoming empowered by the availability of data. Taking this into account, this paper understands OGD as an open system, influenced by its context and environment, where actors use human understandable, machine-readable, government collected and maintained data to drive transparency and the creation of public value.

While it is argued in the academic community that higher levels of transparency and creation of public value are core to the understanding and importance of OGD, numerous other benefits associated with OGD have been discussed. For example, the Open Knowledge Foundation notes that OGD may lead to new services, innovation, and improved efficiency and effectiveness of government services (Open Knowledge International, 2018) and the European Data Portal highlights three main sectors that OGD impacts: government performance, economy, and social issues (European Data Portal, 2018a). In the scholarly literature, some of the benefits most often studied relate to community empowerment (Huber, 2012; Schrock & Shaffer, 2017), the innovative potential of OGD (Juell-Skielse et al., 2014), the creation of new public services (Foulonneau et al., 2014), and transparency (Corrêa et al., 2017).

In one recent example, (Mcbride et al., 2018), present a case study where OGD was used to develop and co-create new services that provide public value. One of the main findings there was that an approach based on agile and lean development led to a more effective service. The study further highlights that agile and lean development methods appear to play a key role in allowing the successful development of OGD-based co-created public services as they allow for more potential co-creation to occur throughout the iterative development cycles.

Though there are examples of when OGD does provide public value, and these expected benefits have materialized, there are often barriers that inhibit these benefits from occurring. These barriers occur at the data, data user, and data provider level, and can be further classified into barriers related to technical, organizational, legal, and personal aspects (Toots et al., 2017). Users of OGD may have a lack of technical understanding to exploit the data and/or may not have time to properly engage with data if it is not clean (Janssen et al., 2012; Young & Yan, 2017; Zuiderwijk et al., 2012). For those releasing the data, there may be no political motivation or incentive, the benefits may not be understood, transparency may not be viewed favorably, there could be legal barriers to releasing data, and the technical skills may not exist to open up data (Conradie & Choenni, 2014; Gonzalez-Zapata & Heeks, 2015; Janssen et al., 2012; Wang & Lo, 2016). Finally, the data itself may be a barrier if it is not clean, lacks metadata, contains many missing values, and is generally of poor quality (Young & Yan, 2017). In order to overcome these barriers, some proposals have been made, such as showing the positive impact of OGD, demonstrating working examples of services built with OGD, engaging in co-creation, developing a self-organized/bottom-up demand for OGD, and making

OGD a political priority (Foulonneau et al., 2014; Juell-Skielse et al., 2014; Kassen, 2013; Khayyat & Bannister, 2017).

The notion of co-creating public services with OGD has emerged recently in the literature as one of the most potentially powerful methods for increasing the usage of OGD (McBride et al., 2018). Studies have shown that by involving different stakeholder groups throughout the process of public service development, it is possible to achieve higher levels of public value from OGD (McBride, 2020). One of the primary reasons for this is that the availability of OGD lowers the barriers for co-creation, by allowing any user to take advantage of OGD to create services that are meaningful to them. In order to take advantage of this phenomenon, some governments are beginning to look towards encouraging co-creative behavior within the context of OGD by embracing hackathons, encouraging communication and interactions, opening their code bases, and placing a stronger emphasis on interactivity in the service design. This new shift could allow for higher levels of OGD usage, which would, in turn, lead to a higher level of performance when it comes to OGD ecosystems.

Systems Theory Background and Core Concepts

Systems theory focuses on understanding the behavior of a system by looking at it as a whole, rather than at its specific parts, and acknowledges that the behavior of a system is largely driven by its architecture or structure. When talking about a 'system', this paper adopts the definition where "a system is a set of entities and their relationships, whose functionality is greater than the sum of the individual entities" (Crawley et al. 2015, p. 9). Additionally, every system will have a **function**, what it does (performance is also mapped to function, and is understood as how well the system does the thing it is supposed to do), a **form**, what the system is, and **concept**, how form maps to function (Crawley et al., 2015). For OGD ecosystems, the function is normative, decided by the society where the ecosystem exists, however, generally speaking, the function of an OGD ecosystem is likely to be related to the availability and usage of OGD. The form is what the system looks like and how the "parts" are put together; for OGD ecosystems specifically, the form is discussed in more detail in the following section of the theoretical background. Finally, concept is how the system's form is used to achieve the function. In the case of OGD ecosystems, the concept may be controlled primarily by political and societal narratives and is highly context dependent. In order to better understand the performance of a system, system architects and those working with systems theory can draw on insights offered from systems thinking, which is an approach that has been developed to understand better the performance of a system by focusing on its function, form, and concept.

While systems thinking provides a way to understand better the system itself, one must also understand their own and society's 'mental models' as it has been posited that "everything we think we know about the world is a model", yet "our models fall far short of representing the world fully" (Meadows 2008, p. 86). Meadows (2008) argues that it is these models that we use to make our decisions; furthermore, it is these shared mental models that dictate our current paradigm, and, as such, also influence how a system behaves and functions as it is from our shared mental models that the nature of reality and system goals originate. Thus, understanding shared mental models and how they influence the system is a critical step when it

comes to studying and analyzing the performance and behavior of a system. Another important contribution to systems theory is that of system dynamics, which provides a framework to study systems over time and cause change by intervening at specific points (Forrester, 1991). System dynamics posits that "systems of information-feedback control are fundamental to all life and human endeavors" (Forrester 2013, p. 15) and highlights the importance of feedback loops in systems. A feedback loop is either balancing or reinforcing and represents a dynamic way for the system to receive "feedback" as an input into its behavior. The purpose of a balancing feedback loop is to maintain system stability; these often trigger if a system is shocked, their goal is to reverse or oppose change (Meadows, 2008). In opposition to this are reinforcing loops, which focus on growth and evolution and encourage change in a given direction (positive or negative) for a system (Meadows, 2008). By studying the dynamics of a system, and identifying the different loops at play, it is possible to better understand the emergent behavior of a system and also identify potential places to intervene, known as leverage points, to alter its behavior or performance.

OGD Ecosystems

The idea of "OGD ecosystems" is relatively new and is still being actively debated and studied with different models of said ecosystems being proposed. In the academic community, there have been a few different approaches to understanding OGD ecosystems: those originating from a business perspective (Heimstädt et al., 2014b; Immonen et al., 2014b; Kitsios & Kamariotou, 2017), those drawing from sociotechnical perspectives (Dawes et al., 2016; Donker & Loenen, 2017; Harrison et al., 2012; Reggi & Dawes, 2016; Styrin et al., 2017; Zuiderwijk et al., 2014), and those which approach it from an innovation ecosystem perspective (Ham et al., 2015; Juell-Skielse et al., 2014). In order to demonstrate the different understandings of OGD ecosystems, Table 1 has been produced that shows a number of different authors' perspectives on the core characteristics of OGD ecosystems.

(Table 1 about here)

There are two core approaches here. The first, as shown in (Immonen et al., 2014a; Kitsios et al., 2017), looks at the OGD ecosystem as a "black box" of sorts, and focuses more on the different actors that are involved in the ecosystem; these sources tend to lie primarily within the business perspective. On the other hand, Dawes et al., 2016, Harrison et al., 2012, and Zuiderwijk et al., 2014 all take a different approach, looking not just at the individual stakeholders, but also taking into account interactions, relationships, and different environmental constraints. However, what is important to point out here is that all of these papers share the view that OGD must be thought of as a system, with (Styrin et al., 2017) making it clear that from their analysis all OGD ecosystems are "dynamic and evolving". Writing in 2012, (Harrison et al., 2012) put forth their understanding of an OGD ecosystem that consists of government policies, innovators, and users working together with OGD. While the authors do not explicitly outline more precise components of the ecosystem, they do provide great value to the OGD ecosystem discussion through their proposal of "strategic ecosystems thinking", which:

> "presupposes a keen understanding of ecosystem components and the linkages between them, and an evolving appreciation for how the interactions among those components are related to the services, programs, and other outcomes of value that are produced, either within a government organization or by organizations external to government but internal to the ecosystem" (Harrison et al., 2012, p. 923).

The authors further argue that by using "strategic ecosystems thinking" it should be possible to enact change through targeting specific weak points within the ecosystem to encourage a change in ecosystem behavior. It must be pointed out that there is a clear relationship between "strategic ecosystems thinking" and the previously mentioned concepts from systems theory, such as system dynamics and systems thinking. So, when talking about "strategic ecosystems thinking", what is meant is the application of systems thinking to OGD ecosystems. However, in order for this application of systems thinking to OGD ecosystems to be successful, two items are needed. Firstly, a more concrete understanding of the different relationships and behavior of OGD ecosystems, and, secondly, a framework or process for not only thinking strategically about OGD ecosystems, but actually enacting change as well. In regard to the first point, two key ecosystem models stand out in the literature.

Firstly, Zuiderwijk et al. 2014 proposed their model which identified five main characteristics of OGD ecosystems: design, context, interdependences and interactions, participants, and data resources and tools. Based on these characteristics, the authors find that an OGD ecosystem should allow for publishing of data, searching of data, cleaning data, and discussing data. When summarizing how OGD ecosystems develop, it was noted that the development or growth of OGD ecosystems takes place through three main processes: user adaptation, feedback loops, and dynamic interactions (Zuiderwijk et al., 2014). This is interesting, and is also mirrored by (Styrin et al., 2017), who note that OGD ecosystems "occur naturally" in the wild, but it is only possible through promotion, incentivisation, and evolution for OGD ecosystems to grow and prosper.

The second model comes from a more recent study that analyzed OGD ecosystems and was conducted by Dawes et al., 2016. In their research, a model was created which provides a clear overview of OGD ecosystems, taking into account the systemic attributes and parts, as well as the external environmental and contextual influencing factors. This model sees three main actors: OGD providers, OGD users, and OGD beneficiaries. Additionally, the model demonstrates how different factors influence the behavior of the ecosystem. As previously mentioned, one of the key factors for conducting "strategic ecosystems thinking" would be clearer insight into the OGD ecosystem at hand. Thus, for the purpose of this research paper, the model proposed by Dawes et al., 2016 has been used as the starting point to analyze Estonia's OGD ecosystems. In regard to the second requirement (a clear framework or process) a six-step process can be derived from the literature on systems thinking, system dynamics, OGD ecosystems, and "strategic ecosystems thinking".

The six steps of this process are as follows:

1. Model and understand the form, function, and concept of the system.
2. Analyze the shared mental models influencing the system.

3. Study and understand the current behavior of the system.
4. Identify the feedback loops in the system.
5. Intervene in system at identified feedback/leverage points.
6. Watch, observe, and monitor changes in performance/behavior.

In the first step, the model proposed by Dawes et. al., 2016 is used to model and understand the form and concept of the OGD ecosystem. The function and the performance are more subjective and dependent on the goals in a given context for the OGD ecosystem. Steps 2 and 3 are influenced by ideas from systems thinking and systems theory and aim to provide a better understanding about how and why the system modeled in step 1 is performing as it does. Steps 4 through 6 are heavily influenced from systems theory and systems dynamics and focus on identifying the feedback loops within the ecosystem that are responsible for inhibiting or driving the ecosystem's behavior. This entire six-step process can be understood as a process or framework for engaging in "strategic ecosystems thinking". This framework was applied in this research, and an example is given later in the discussion section of the paper. It is argued in this paper that by following this six-step process, researchers, policy makers, or those playing a role in the development of an OGD ecosystem should be able to: firstly, understand their own OGD ecosystem better; secondly, analyze how different mental models affect the performance and function of the ecosystem; thirdly, understand the importance of feedback and non-linear behavior for OGD ecosystems; and, finally, to generate the confidence and capability to enact strategic change in OGD ecosystems by making specifically targeted interventions that aim to improve the performance of the ecosystem.

In order to further operationalize and guide the research, some core hypotheses were formulated that drew on insights offered from the proposed six-step framework for engaging in "strategic ecosystems thinking" and by reflecting back on the insights offered from the theoretical background. These hypotheses are all related to the goal of improving the performance of OGD ecosystems and are as follows:

1. Due to the systemic nature of OGD, a **holistic approach** addressing the different institutional, political, social, and technical dimensions is likely to support both the provision and usage of OGD and thus lead to higher levels of performance.
2. With a view to enhancing the interaction of stakeholders within the OGD ecosystem (data providers, users, beneficiaries), and thereby encouraging the production of public value from OGD, following an approach based around **co-creation** for an OGD ecosystem should lead to higher levels of performance.
3. Meaningful co-creation requires high awareness and easy access to the co-creation process. Hence, higher levels of **openness and transparency** of the process should lead to higher levels of performance.
4. For the purpose of fostering feedback loops in the ecosystem, an iterative approach based around **agile and lean development** is likely to lead to higher levels of performance.
5. By **understanding the system**, it should be possible to identify the present feedback loops and make strategic changes to encourage positive reinforcement loops to drive higher levels of performance.

Methodology

The action research intervention started in February 2018. However, preparatory research that made the intervention possible was conducted already in 2016-2017 when the researchers were engaged in studying and working with Estonia's OGD ecosystem as part of the EU Horizon 2020 funded OpenGovIntelligence project. Throughout that project the researchers were directly engaged with a wide variety of stakeholders to understand how OGD was being used in Estonia and, more specifically, how new services could be built through the exploitation of OGD. The preparatory stage in 2016-2017 involved collecting data from national stakeholders on their perceptions of the barriers and gaps in the Estonian OGD ecosystem through an online survey, personal interviews and workshops (see the details in Table 3). These data were reused and expanded on later during the action research initiative.

In November 2017, the Ministry of Economic Affairs and Communications (MoEAC, the Estonian ministry responsible for the development and maintenance of Estonia's OGD initiatives and information society) launched a procurement titled "Promoting the Use of OGD". Their aim was to engage an external partner to support the implementation of Estonia's open data policy and help improve the provision and use of OGD in the country. The contract for the three-year collaboration (2018-2020) was won by Open Knowledge Estonia, a local Estonian NGO founded at the end of 2016, who then approached the researchers with an explicit goal of bringing research competence to the project team. The action research for this paper started at this stage.

As the researchers had the opportunity to shape the development and implementation of the project activities, a research design based around action research was adopted. Action research starts from an understanding that "complex social systems cannot be reduced for meaningful study" (Baskerville 1999, p. 3) and "aims to solve current practical problems while expanding scientific knowledge" (Baskerville & Myers 2004, p.329). Action research has been deemed an acceptable methodology when the researcher is 1) actively involved, 2) the knowledge can be immediately applied, and 3) the research links theory and practice (Baskerville, 1999). Action research is generally conducted following a five-stage iterative model consisting of diagnosing, action planning, action taking, evaluating, and specifying learning (Baskerville, 1999). This five-step iterative process was adopted for this research and the overarching approach is demonstrated on Figure 1.

At the start of the research, an overarching understanding of the as-is situation was informed primarily from two sources. Firstly, the researchers were able to directly provide input due to their experience and previous research on the topic. Secondly, in the procurement set out by the MoEAC, a list of performance goals was set out (see Table 1 below). While each of these key performance indicators addresses something different, be it political engagement, the open data portal, or news and dissemination, they all related back to the Estonian OGD ecosystem. Thus, an overarching research question was drafted that reflected the systemic nature of OGD in Estonia and the key expectations from the MoEAC: "How to improve the performance of Estonia's OGD Ecosystem?". The definition of 'performance' adopted for the purpose of this

research relates back to the procurement requirements and to the definition offered in the introduction of this paper. In short, based on the current theoretical understanding of the key elements of OGD ecosystems and the ministry's project objectives, ecosystem 'performance' was contextualized as involving the dimensions of 1) OGD supply, 2) OGD usage, and 3) communication, interaction and linkages between OGD suppliers, users, and beneficiaries where higher levels of each would be associated with higher performance (these stakeholder category groups mirror those proposed in Dawes, et. al., 2016). The action research thus set the objective of 1) increasing OGD supply in Estonia, 2) increasing OGD use in Estonia, 3) improving communication and interaction between OGD stakeholders. The goals of the project and the related performance categories are shown in Table 2.

(Table 2 about here)

Starting from this foundation, the researchers continually iterated through the action research framework in a systematic way. When going through the five stages of the action research process depicted on **Error! Reference source not found.**1, the six-step process of analyzing and improving OGD ecosystems introduced in the theoretical section was applied in the following manner:

- In phase 1 (action planning), the *as-is* of the Estonian OGD ecosystem was analyzed to understand the form, function and concept of the system, as well as the mental models influencing the system (based on stakeholders' perceptions), current behavior and feedback loops in the system. This corresponds to steps 1-4 in the six-step framework described above.
- In phase 2 (action taking), the researchers collaborated with civil society and government policy-makers to intervene in the system at the identified feedback/leverage points. This corresponds to step 5 in the six-step framework.
- In phase 3 (evaluation), changes in performance/behavior were monitored and evaluated. This reflects step 6 in the six-step framework.
- In phases 4-5 (specifying learning and diagnosing), next steps of the intervention were planned and the approach adapted, if needed, to address the observations from the evaluation phase.

Once a month, the researchers met together with MoEAC to discuss what had been done in the past month, what the results were, what went well, what did not, and then the next month's activities were planned. The results of these meetings were made publicly available on GitHub, where anyone was able to see closed issues and future development goals. The development was heavily influenced by agile and lean development methodology with sprints being defined and explicit tasks being developed and co-created between parties. This development approach is shown in Figure 2.

(Figures 1 and 2 about here, side by side)

The evaluation of the taken actions took place in a variety of ways. There was direct feedback from the MoEAC, feedback received from experts involved in Estonia's public sector OGD working group, feedback

received from workshops and experts on OGD in Estonia, and also via comments through social media platforms and collaboration workspaces such as GitHub. After each month's sprint the specific results and learned knowledge were recorded. Based on these data, an ongoing monitoring of the situation took place once a month, while a more thorough evaluation of the results of the intervention was conducted in August-September 2019, when the researchers analyzed the overall progress in relation to the initial project and research objectives.

In terms of data collection, a wide variety of different sources have been used: direct participation, GitHub issue and pull request history, semi-structured interviews, official government policy documents, internal government discussions, meeting minutes, workshop feedback, and survey information. Overall, a large amount of empirical data has been gathered and consulted in order to ensure higher levels of internal validity of the study and to better support and relay the research to readers. The data sources, along with their role in the research, are summarized in Table 3.

(Table 3 about here)

One of the main strengths of the action research approach – researchers' involvement with the case they are studying and unique access to insider information – also entails possible limitations and risks that may challenge the validity of the research findings (Davison et al., 2004). The most obvious one is the risk of subjectivity and bias in interpreting the results of the intervention. In order to mitigate the risks and minimize issues with internal validity, the research made use of multiple sources of evidence to validate the findings (see Table 3 above). The triangulation of data sources and collection and analysis methods is commonly considered an appropriate counter-mechanism to validity issues, which often arise in studies involving the examination of one single context. When validating the findings, the research team also heavily relied on evidence obtained from external, objective sources, such as the EDP's and OECD's comparative evaluations of the state of OGD in different countries.

Estonia's OGD Ecosystem

OGD Ecosystem Before Intervention

Setting. Estonia, a small country of 1.3 million inhabitants, has the reputation of being one of the world leaders in digital government (Kalvet, 2012; Kitsing, 2011). Despite Estonia's high level of e-government development, historically it has been one of the worst performing European countries when it comes to OGD (McBride et al., 2018a). At the same time, Estonia is generally considered to provide good conditions for public access to government information – it has a Public Information Act in place since 2000 and consistently receives the highest scores for government transparency in international rankings such as the Freedom in the World report (Freedom House, 2017). The main problem with regard to public sector information has thus not been citizens' access to information as such but in government data being mostly

available in formats which do not allow for downloading, easy processing and reuse of the data (McBride et al., 2018a).

One of the keys to understanding the public governance and policy-making setting in Estonia is its small state context. Estonia's tiny population has been associated with particular characteristics of public administration and policy, such as a high level of personalism and reliance on informal structures rather than highly formalized processes (Sarapuu, 2010). This may explain why a small group of civil society activists and individual experts had been able to acquire an important role in influencing the development of OGD in Estonia even before the start of the Open Knowledge Estonia's official cooperation project with the MoEAC.

Global and national influences. The fact that OGD entered Estonia's policy agenda in the first place is largely due to international influences. While digital access to public information existed since the early 2000s, the concept of OGD as it is understood today was first introduced into policy discussions through the global Open Government Partnership process, which Estonia joined in 2012. Estonia's OGD policies have also been influenced by the OECD's analyses, the G8 Open Data Charter and EU-level interoperability initiatives such as the ISA program (Vabariigi Valitsus, 2014). Although there was external pressure to conform and offer OGD, Estonian policymakers still saw little value in OGD and made minimal efforts to improve.

Policies and strategies. Due to Estonia's limited resources, its e-government policies have been highly driven by the government's goal of creating a minimalist and efficient state (Kitsing, 2011) and, as "OGD has been viewed as a tool for transparency and openness towards the citizenry instead of something that could easily generate revenue or savings" (p. 622), OGD has not been high on the government's priority list (McBride et al., 2018a). However, due primarily to external pressure from the international community and some local experts and civil society, OGD was taken up in the policy agenda in 2012. This led to the adoption of a Green Paper (government policy document) on OGD and the subsequent release of a national OGD portal later on in 2015. While the creation of the portal and official policy guidance on OGD was being created, the Estonian Information System Authority created a new funding opportunity to support the publication and reuse of OGD. However, until the closure of the scheme in the summer of 2019, these funds were severely under-used by public sector organizations.

By 2015, Estonia therefore had a legal framework for OGD, a policy strategy in the form of the Green Paper, a central repository for OGD and funding measures. However, due to the lack of active policy coordination and limiter human resources at the MoEAC, public sector organizations were largely left to their own devices in publishing OGD and made very little actual progress in complying with the policy.

Data publication. Until the start of this research, public sector organizations had mostly been passive in publishing OGD. At the beginning of 2018, only 70 datasets were available in the national open data portal. Estonia's IT interoperability framework and the Green Paper required data holders to create an open data catalog on their official website with all information and metadata on their open data as well as online forms

for requesting open data. Data holders were also required to link their website to the national OGD portal. In many cases this was not done in practice – individual organizations such as the Land Board had a number of open datasets available but not linked to the portal. As an example, the Land Board provided their own website and online (map) applications for accessing their data but the data was often not available in downloadable and machine-readable formats. Therefore, in many cases, users interested in getting access to public data needed to go through a cumbersome process of individually e-mailing the data holders to request the data and sort out the conditions on which the data could be used. In the experience of some the authors of this paper, this process could take as long as several months.

Previous research has identified the existence of the national interoperability infrastructure, the 'X-Road', as one of the reasons for the lack of open data (McBride et al., 2018a). As government institutions commonly use the secure data exchange layer X-road for exchanging data and reusing data within the public sector, they have lacked the urgency of publishing their datasets as open data.

Data use. At the beginning of 2018, the national OGD portal contained information on four applications that had used OGD. Some more reuse cases existed in practice, such as some applications that were developed in 48 hours during an Open and Big Data Hackathon organized by the MoEAC at the end of 2016. However, almost all of them remained one-off exercises which were never continued after the end of the hackathon. Government institutions themselves were also providing data-driven applications and services to the public (e.g. the Land Board's map applications or the Ministry of Finance's overview of state budget). However, the data used in these applications was often times not 'open' and reusable by other parties. The lack of open data reuse was of course quite natural given the low availability of OGD to begin with.

Feedback and communication. One of the core weaknesses in Estonia's OGD ecosystem was the lack of feedback and interaction between OGD users, OGD providers, and OGD beneficiaries. As a characteristic of a small state, some informal and personal communication existed between individual people working with OGD in the government or civil society. Occasional events such as the Open and Big Data Hackathon in 2016 served as platforms for dialogue and collaboration but the feedback mechanisms were not strong nor sufficiently institutionalized to create a genuine understanding of the mutual needs and possibilities on both sides.

Benefits. Writing in 2017, researchers reported that the benefits of OGD were poorly understood in Estonia (Toots et al., 2017). Due to the existence of the data exchange layer X-Road and lack of well-known cases of OGD reuse, Estonian experts and policymakers remained skeptical of OGD being able to provide benefits that would exceed the costs of opening the data. Although the Green Paper mentioned several potential benefits of OGD based on international research, the government had made no attempt to develop an approach for understanding the benefits of OGD in the Estonian context.

Identified Weaknesses

Based on the initial analysis of the system, there appeared to be a few areas of weakness that were limiting the performance of Estonia's OGD Ecosystem. One of the clearest weaknesses related to the **prevailing mental model** in place in Estonia that viewed OGD as outdated, or something not needed for a digital society. For example, Taavi Kotka, the Estonian CIO often credited with bringing Estonia's digital government solutions to the world, noted that "Open data in the meaning that you're actually going to take data out from the database and put it somewhere in the portal, it's just so last century" (MeriTalk, 2016). To some extent, this view made sense based on how Estonia's digital society operated and interoperability through the X-Road platform allowed government agencies to freely and easily exchange data. In previous studies, the existence of the X-Road for the movement of data has been shown to be one of the biggest (mental) barriers when it came to the use or release of OGD (Toots et al., 2017). As OGD was not viewed as a high priority area and, by many, viewed as some form of backwards progress, many government agencies did not feel the need to participate in the release of OGD.

A second weakness identified relates to the **legal situation** of Estonia. While, in fact, organizations are required by the Public Information Act to make any public data available if it is requested, many organizations viewed it as easier to be *reactive*, only providing data when requested, rather than *proactive*, providing data in advance. As there is no law in Estonia requiring government organizations to provide access to their OGD via an open data portal, there was little to no incentive to do so. Secondly, due to the nature of Estonian law, any sort of license applied to an OGD set, for example CC4.0, technically becomes more restrictive. Due to the ambiguity of licensing of OGD in Estonia, many organizations have been hesitant to release data or provide a license, thus limiting the **reusability** of OGD.

The third identified weakness is related to the **awareness and use of OGD**, both of which were low. The first real attempt at boosting the use of OGD came in 2016, when the MoEAC organized a hackathon that focused on using OGD. During the organization of this event, it became clear that there were some OGD sets available in Estonia, but they were not in the same place. In order to remedy this, a crowd-sourced Google document was created that listed different available datasets and where they could be found. Interestingly, almost none of the datasets used were actually available on the official OGD portal of Estonia. When it comes to awareness of OGD, this remained low across businesses, civil society, and at the governmental level. Since the data did not exist, people could not use it or did not know what OGD meant. On the private sector side, there was some knowledge of OGD, but use remained limited due to there being a small supply of OGD that could be used, and, additionally, because of Estonia's small market size no viable business models had been found to utilize OGD. At the governmental level, as OGD was not viewed as a priority, there was little to no use of it, no successful examples of OGD creating public value in Estonia, and little demand for it. It was not given much attention, even though in 2014 the Green Paper on OGD was released and in 2015 the first OGD portal was launched. Finally, it must also be noted that, while funding and cost is often highlighted as a barrier for the release of OGD, this was not the case in Estonia. In fact, a

fund was created with money available explicitly created to help agencies open up their data, but this fund received almost no use, primarily due to lack of interest.

The final weakness that was identified was technical in nature and related to the **OGD portal** of Estonia which was built in 2015. This portal was built following a waterfall-based approach, released to the public, but not maintained or updated. Additionally, as there were no requirements for government agencies to put their data on the portal, its use remained minuscule, with only 10 out of some 3,000 government agencies adding their data there at the earlier stages (Kuul, 2015). The portal was based around the United Kingdom's Drupal – CKAN OGD Platform and allowed for ministries to add their data to the OGD Portal. However, due to lack of maintenance, the portal quickly broke down and many features that made CKAN useful, such as data harvesting, were never used. Interestingly, as noted previously, many OGD sets were available, just not on the portal. Thus, it was hypothesized that one of the main reasons for the lack of use of the OGD portal was due to either technical confusion about how to access and add data to the portal, or due to the extra time required to invest in keeping data uploaded and up-to-date as it was something not readily-includable in the normal business process. Since the portal did not have many datasets available, it also did not receive a high number of users, thus continuously driving a reinforcement loop in a negative direction. That is to say, there was no data available, so people could not use data, this then appeared as lack of demand, which further drove lack of access to data.

Though the weaknesses here are discussed on their own, what is clear is that many of these weaknesses were being reinforced in a negative fashion via **feedback**. So, any attempt to address these weaknesses to improve the performance of Estonia's OGD ecosystem needed to be systematic in nature and, also, aim at either the creation of new positive reinforcement loops or changing the negative reinforcement loops into positive loops.

System Interventions

As previously noted, the initial Estonian OGD Ecosystem suffered from a negative reinforcement loop between OGD users, OGD providers, and OGD beneficiaries. Though funding was available, due to the lack of political interest and high levels of technical complexity, there was no real incentive or requirement for data holders to make their data available on an OGD portal. On the other hand, potential OGD users did not know what data existed or what the quality of the data was and, as such, were unable to clearly understand what data they could potentially access or how it could be used. Thus, data that was published and made open was often times due to a sense of duty, a strong belief in openness by an agency's employee, or due to an explicit command. Interestingly, there is one primary exception to this rule, and that is data maintained by the Estonian Land Board, which as part of the INSPIRE initiative ran their own fully functional OGD portal due to EU regulations, further demonstrating the power that proper legal frameworks can have on driving the release of OGD.

In order to counter this feedback loop between OGD users, OGD suppliers, and OGD beneficiaries, an explicit feedback mechanism was designed to allow the data holders to have a more functional dialogue

with the open data community. As the OGD ecosystem is, by definition, a complex adaptive system, the feedback loop was designed to be lightweight and adjustable to that it can be easily developed and altered as the system reacted. This feedback mechanism took the shape of a GitHub repository, where all discussions related to particular datasets available, or requests for datasets not yet available, could be harbored and directed to the appropriate data holders through a series of flags and tags. In addition to this, a grooming process was implemented that intended to go over each data request and channel them to the appropriate implementation mechanisms. As part of the GitHub issue-tracker process, data holders (government agencies) have created GitHub accounts and play an active role in the discussion process, these GitHub accounts are mapped to the organization and the employee to ensure transparency. For example, if someone requested data from Ministry A, the request would be sent to Ministry A's GitHub contact and dealt with. Interestingly, while initially designed to facilitate communication between data holder and data user, what has been noticed is a strong bottom-up/crowdsourced approach, where a data user asks a question or makes a request and other users step in to provide answers. This has, thus, not only helped to drive communication between OGD users, OGD providers, and OGD beneficiaries, but also helped create new interactions between data users thus expanding the network of Estonia's OGD Ecosystem's data users. Between May 25th of 2020 and February 16th 2017 a total of 237 issues have been filed, with 137 of them having been closed and the other 100 being discussed or waiting for answers/updates still. Although the number of issues processed is not large in relation to the weeks that have passed, the issue tracker has served as a key condensation nucleus for the OGD community, the data holders, policymakers, and drivers of the ecosystem. This is signified by numerous issues being followed by long threads of conversation involving members of each of the mentioned stakeholder groups.

As Estonia's OGD Ecosystem began to grow, a shift in the mental model of OGD by the government in power became increasingly clear. In September of 2018, the Minister of ICT and Entrepreneurship, Rene Tammist, said that if Estonia wanted to advance and truly be a leader in e-Government, OGD must be made a priority (Tammist, 2018). Around the same time, Estonia hired its first Chief Data Officer, in August of 2018. This shift in understanding about the importance of OGD led to a large increase in the awareness of OGD and also led to many articles being published in Estonian media that either discussed OGD or used OGD sources for data journalism. While, undoubtedly, there are other drivers behind the political and mental model shift about OGD, it is also clear that the rapidly developing ecosystem played a role. One exchange clearly demonstrates this shift. On 14th January, an article discussing Estonia's lackluster performance on international rankings related to OGD was released (Lõugas, 2019b), and, the same day, five hours later, the Chief Data Officer responded to the media noting that there is now an active GitHub environment with clear demand for OGD, and that agencies in Estonia were not fulfilling their obligations to offer OGD, so, from that point, agencies that received structural funds from the European Union and were legally obligated to open up their data would be required to do so (Lõugas, 2019a). This shift also has been influenced by Estonia's commitment towards becoming an AI-driven government, known as the Kratt initiative, which will require data of higher quality to be available and maintained within the country. There is, therefore, increased focus on data governance, data maintenance, and data availability to lay the framework for future

AI-based projects within Estonia. This shift created a new area of feedback in Estonia's OGD Ecosystem, where there was now a political and legal requirement to open up data, thus helping to drive the availability of new datasets.

Another faulty feedback mechanism identified was related to the OGD portal itself. At the beginning, it was not clear if the operating portal was the problem, or rather the lack of awareness and lack of political priority was causing low use. Thus, the initial idea was to simply update and maintain the OGD portal. However, it quickly became clear to all involved that there were numerous severe technical challenges facing the first OGD portal and it was only possible to update and maintain it through a relatively complex and costly process for both the OGD holders and the OGD portal maintainers. These barriers were both technical (responsiveness, source code problems, architectural issues, technical debt, lack of flexibility, etc.) and process-related (authorization process for data publishers, access and handover, strict publishing criteria, etc.). As a result of these issues, the portal was slow to respond to the rapidly growing expectations and needs of the community. Thus, it was decided to expend energy on the creation of a more transparent, agile, and faster-moving feedback mechanism, a new OGD portal based around JKAN (https://jkan.io/, accessed 29.05.2020). As stated in the methodology, the development of this portal took place following an approach based on lean and agile development. The first version was released in November 2018 as an MVP, and, since then, more development sprints have been conducted, with each sprint improving the quality of the portal and taking into account different requests, feedback, and needs from both OGD users, OGD providers, OGD beneficiaries, and the government. As lack of transparency, low responsiveness to change, and lack of flexibility were identified as key inhibitors of Estonia's OGD Ecosystem and the previous portal, the technology used for the new portal was explicitly chosen for its radical transparency (the entire codebase, datasets, changes, uploads, dataset deletions, etc. are available as open source online for anyone to contribute to or monitor), simplicity, and the speed of development. Additionally, the portal is front-end only, allowing for the portal to pivot easily as needed to keep in touch with the demand of the ecosystem. It was noticed that almost every Estonian government agency had some form of OGD available on their own webpage, so, the decision was made to simply create a portal that served as a directory, allowing Estonian government agencies to keep their data on their own servers, and simply have users directed there from the Estonian OGD portal. This minimized the business process disruption to Estonian government agencies (simply add a link to your dataset once and the data will always be up to date) and allowed for quick and rapid growth, thus providing increased levels of performance and providing higher levels of value to the OGD Ecosystem.

The transition to the new portal did not align well with the status quo both in Estonia and in the international community about how OGD should be done, thereby facing high levels of resistance initially. However, by January 2019 (3 months after the launch of the MVP), it became clear that the portal was seeing increased levels of usage and engagement with a 95% increase in average session duration, a 32% increase in session count, and a 30% increase in pages per session. Additionally, as of April 2019 (6 months after the launch of the new portal), the number of datasets available increased from 70 to 170 and the

number of applications using OGD from 4 to 17. Both figures increased even more throughout the next year (As of May 2020 there are 61 applications and 582 datasets on the portal). These improvements also materialized as a large increase in Estonia's ranking in the European Data Portal's Open Data Maturity Index where Estonia increased from 27th to 14th place in the rankings (European Data Portal, 2019). Thus, by decreasing the barriers to adding data to the portal, increasing transparency, and encouraging interaction and communication, the OGD Portal of Estonia has rapidly grown and seen increasingly high levels of performance.

While the previous changes happened primarily online, the final change implemented happens in-person. Previously, there was little face-to-face discussion about OGD or events focusing specifically on OGD. Thus, three different forms of face-to-face interaction have been organized to help bolster Estonia's OGD ecosystem. At the higher political level, an expert working group has been established that brings together high level stakeholders from Estonian governmental agencies to discuss OGD and strategize about approaches. The working group meets three times a year and shares information via e-mail in between meetings. Secondly, public events have been organized, such as the annual informal Open Data Day and the more high-level Open Data Forum, which allow for anyone interested in OGD to listen about developments in the OGD ecosystem and interact with other data users and holders, thus further increasing the interaction between members of the ecosystem. In the two years that the Open Data Forum has been organized, more than 100 participants from the public, private, non-governmental and academic sectors have taken part each year. Finally, the grooming sessions for the open data issuer tracker are open to the public, with any interested party able to come and discuss the current issues related to OGD availability and actively contribute to Estonia's OGD ecosystem. Thus far participation has been low in this area, but is slowly increasing with members of private sector companies and concerned citizens increasingly attending the meetups.

Discussion and Findings

The primary aim of this research was to both simultaneously improve the performance of Estonia's OGD Ecosystem, and also to research in an academic manner whether or not an ecosystem-based approach could provide a viable framework for OGD ecosystem performance improvements. This research offered a conceptualization of performance for OGD ecosystems on a three-dimensional basis – OGD supply; OGD usage; and communication, interaction, and linkages between OGD suppliers and users – where higher levels of these dimensions would indicate a higher level of performance. Reflecting back on the status of the OGD ecosystem at the beginning of the research, as demonstrated in Table 2, it is possible to see that a large increase in performance can be identified:

- The number of datasets has increased from 70 to 582;
- There is a large increase in the usage of the OGD portal in terms of unique users (Before the procurement, in the period of January to May 2017 there were a total of 6300 unique users, during the same period in the year 2020 there were 12877 unique users, an increase of 204%);

- The number of applications on the portal has increased from 4 to 61;
- A public sector working group has been reestablished and meets three times a year at a minimum;
- There are numerous OGD events being held, including those coming up in a self-organized manner, with no involvement from the government or OKEE;
- News articles have emerged on OGD in Estonia. Primarily these cover blog posts published to the open data portal, current events in OGD, new applications, or different political issues around the availability or lack thereof when it comes to OGD;
- There are two primary Facebook pages for OGD in Estonia, OpenESTdata, which has 635 members and facilitates discussion about open data in Estonia, and Open Data Estonia, which has 738 likes and serves as a central information point for events and updates about OGD in Estonia. The number of participants in these communities has substantially increased but not yet reached the procurement goal (1000);
- Estonia has increased in the international rankings. In the European Data Portal's Open Data Maturity report, Estonia has risen from 27th to 14th place (European Data Portal, 2019).

In addition to this, the source code for the portal itself is used and viewed widely, with both government employees and OGD data users making pull requests, raising issues, and providing suggestions on how to improve the overall quality of the portal and the OGD available. There has been empirical examples of citizen or interested stakeholder input creating value for the OGD portal through their suggestions, and this is only possible due to the transparent and open-source nature. This, when combined with the online issue-tracker discussion area, which was highlighted as a positive innovation in a recent OGD report (Blank, 2019), has led to a strong network of data holders and data users actively pushing for more and better OGD in Estonia. Interestingly, one of the unintended side effects of this work has been the rapid spillover effect with OGD being actively taught to government ministers, in university education, and leading to the creation of new courses. Furthermore, awareness in Estonia about the topic of OGD has also grown rapidly as local media outlets have begun covering the topic and even beginning to utilize OGD in their data journalism efforts. Data users have also been able to drive important conversations in Estonia through their use of OGD. One such article by Peek, 2018 demonstrated how many companies at the same address owed tax debt, this led to multiple interviews and in-depth investigations by the mainstream media. Finally, the in-person events relating to OGD have also become increasingly popular: the last Open Data Forum event had over 200 people express interest in attending, but there was only room for 100, further demonstrating the current interest about the topic in Estonia.

While the results are promising, what is likely to be of more interest is the *process* that was undergone to get to this point. To this end, the research framework that was adopted to influence and change the performance of Estonia's OGD ecosystem does seem to be effective. This framework consisted of six main points:

1. Model and understand the form, function, and concept of the system: For this stage, the researchers adopted the model put forth by Dawes et al., 2016, which was effective for understanding the form and concept of the system. The function and performance was more specific to Estonia's context.

2. Analyze the shared mental models influencing the system: With the initial model in place, it was noticed that there was a shared mental model among Estonian government ministries that OGD was not needed or was even an antiquated idea. Thus, one of the most important steps of the research was to actively change this mental model. This was done by integrating the importance of OGD into Estonia's identity as an e-State, where OGD became a core component of this identity, thus becoming something necessary rather than optional.

3. Study and understand the current behavior of the system: At the beginning of the research, the system was not functioning or performing well. There was a limited level of usage. OGD users, OGD providers, and OGD beneficiaries were not communicating, and there were almost no examples of actual impactful use cases of OGD in Estonia.

4. Identify the feedback loops in the systems: three main negative reinforcing loops impacting the performance of Estonia's OGD ecosystem were identified: 1) communication between OGD users, OGD providers, and OGD beneficiaries, 2) mental models associated with OGD, and 3) the use of the OGD portal by data users and data holders.

5. Intervene in the system at identified feedback/leverage points: As these three feedback loops were self-destructive and reinforcing negative behavior, interventions were targeted at these points. Firstly, it was clear that communication and flow of information was key. To this end, communication between OGD users, OGD providers, and OGD beneficiaries was set up through numerous mediums, both online and in-person (such as increased events, open source of the OGD portal code, and the open data issue tracker). Other ways of addressing communication and dissemination issues included writing blog posts that dealt with societally relevant topics and relied entirely on OGD, issuing press releases, and building applications that used OGD. Another intervention targeted the mental models that were inhibiting the usage or release of OGD. While this was addressed via increased dissemination about OGD, another intervention targeted the legal compliance of organizations with regards to opening up their data by reminding governmental organizations of their legal obligation to open up data. This helped to change the behavior of many organizations. In regard to the loop associated with the portal, a new light-weight solution was developed in a way that reduced its burden on data holders while simultaneously improving the accessibility of data for data users.

6. Watch, observe, and monitor changes in performance/behavior: As it stands, the changed feedback loops appear to be positively reinforcing the performance of Estonia's OGD ecosystem driving higher levels of use, more data, more applications, and more interaction between OGD users, OGD providers, and OGD beneficiaries.

Though this research presents results from Estonia, the researchers argue that this framework should be useful for any stakeholder who wants to understand better or enact change within their own OGD ecosystem. Reflecting back on the initial hypotheses, it is possible to make some claims that, based on this

case, appear to be empirically validated. In regards to the first hypothesis, it does appear to be the case that a holistic approach is beneficial for increasing performance in OGD ecosystems. By decreasing barriers to the access of OGD, encouraging transparency, increasing awareness, and creating events that focused on OGD, it raised it as a political priority, which led to increased levels of data availability, which further drove usage and awareness.

Similarly, in regard to the second and third hypotheses, by maintaining the source code in an open-source manner and by encouraging interaction and user involvement, stakeholders played a direct role in helping to develop the OGD ecosystem, which further created a feeling of ownership or importance. By utilizing GitHub for the OGD portal, every government agency had to have an individual create the datasets on GitHub, and interact with citizens on GitHub about OGD, it made something that had previously been an abstract or unpopular concept more tangible, the data owners wanted people to use their data, they wanted to know how it was used, and they wanted to look good publicly. On the non-governmental standpoint, citizens and businesses were able to easily access and communicate with data owners and thus played a direct role in helping to open up data, and, through the use of data, further demonstrate its value.

The fourth hypothesis claimed that an iterative, agile, and lean development approach would lead to higher levels of performance. By decreasing the development time, it was possible to adapt easier to stakeholder feedback, ensuring that the portal was able to do its job, providing data, in as an efficient way as possible. Interestingly, one side-effect of higher levels of transparency and increased attention given to OGD has been the **negative feedback** received by users which has effectively led to even **higher** levels of engagement and performance. As the initial OGD portal was released as an MVP, users noticed where the shortcomings were, and actively provided feedback or made direct contributions as well, improving the overall quality and performance of the portal. In a similar vein, those who felt that they should not have to open up their data or those who demanded more data than were available, began to contribute to discussions at in-person events and online at even higher levels.

Finally, hypothesis five, argued that it is possible, by understanding the parts and behavior of the system, to identify where feedback loops did or did not exist. In the case of Estonia, three primary feedback loops were identified as causing negative behavior in the system 1) lack of feedback and interaction between OGD users, OGD providers, and OGD beneficiaries; 2) the mental models associated with OGD; and 3) the OGD portal's behavior. With these feedback loops identified, it was possible to propose systematic changes that would hopefully alter the behavior and lead to improvement in performance. These changes focused on increasing communication, interaction, and adapting to current data owner business practices, thus removing paint points from the OGD users, OGD providers, and OGD beneficiaries which encouraged increased levels of information flow and interactivity.

Conclusions

The aim of the research in this paper was to answer the question: "How to improve the performance of Estonia's OGD Ecosystem?" and provided an overview of how Estonia's OGD ecosystem was transformed

in a systematic way by drawing on ideas from Systems Thinking, Systems Dynamics, and Systems Theory. Starting from an understanding that Estonia's OGD ecosystem was performing poorly and could be improved, a systematic approach was undertaken to understand why this ecosystem was not performing as one would expect, especially in a country that is known internationally as a leader when it comes to all things "E".

Previous research has identified key drivers and barriers that effect OGD, but often times these barriers and drivers are viewed individually, not within their systemic context. Thus, it was argued that in order to truly understand the issues facing an OGD ecosystem, a more systemic approach was needed. To this end, the authors adopted a previously constructed model of an OGD ecosystem which provided an overview of the different environmental and systemic actors and relationships and provided a strong starting point for the analysis of Estonia's OGD ecosystem. Dawes et al., 2016 posited that their model should aid and assist those who wish to design, plan, analyze, or understand OGD ecosystems and, to this end, the research conducted here does appear to validate their model.

While the research question for this paper is highly focused and relevant for Estonia itself, results of this research appear to be of scholarly value and relevant for any stakeholders involved in OGD as it makes new and relevant contributions to the current literature and understanding about OGD ecosystems. The first contribution of the paper is its role in empirically validating that an ecosystem based approach to OGD does indeed appear to be useful when it comes to enacting strategic change in OGD ecosystems. The ecosystem approach allows for a more in-depth understanding to be gained of how different interactions and relationships influence of the system at large and assists researchers in not only identifying the parts of the ecosystem, but understanding how their interactions effect performance. The second contribution of the paper is the development of a six-step framework that draws on systems thinking, system dynamics, and OGD ecosystems to propose a process for understanding OGD ecosystems and make strategically targeted interventions to achieve performance gains. Additionally, this framework was mapped back onto the action research framework shown in Figure 1, which should allow for other researchers interested in the process to replicate it.

A third contribution of the paper is related to the conceptualization of performance as it relates to OGD ecosystems. Performance is defined as consisting of three parts: OGD availability, OGD usage, OGD communication. These three aspects behave in a systemic/dynamic way, that is to say, they are not linear. An increase of X in OGD availability does not necessarily lead to an X increase in OGD usage. It is, therefore, important to gather a deep understanding of the OGD ecosystem, utilizing the framework in the second mentioned contribution, to understand how small changes in each of these metrics effects the other. Finally, the fourth contribution, is the identification of what appears to be a key component of OGD ecosystems: feedback loops. This paper highlights the importance of identifying where feedback loops currently exist, or where they should exist, but are currently absent. Following this identification and understanding, it is possible to make targeted changes to these loops that should help to change the behavior of the system at large. In this paper, three primary loops were identified and targeted for manipulation.

In addition to these contributions, based on the initial results of this research, it is possible to make some initial insights that are likely to be useful for anyone interested in studying or working with OGD ecosystems:

1. Mental models are important. If the mental model does not support the goal of the ecosystem, change and performance is unlikely to occur.
2. Change the rules and challenge the paradigm if needed, sometimes the status quo limits a system's ability to function and perform as it should.
3. While top down political support is important, it is also possible to drive higher levels of performance by designing a system to support self-organization: encourage new ideas, new ways of participation, and new ways of thinking.
4. High levels of transparency and decreased barriers for co-creation help to create a stronger network within the ecosystem, a sense of ownership around OGD, and increase performance.
5. Communication, discussion, and feedback are key. Interestingly, sometimes negative feedback can be one of the strongest drivers, by bringing awareness to the situation and encouraging stakeholders to participate.
6. Releasing an MVP and following an iterative/agile development approach encourages feedback and communication.
7. A weaker technology that reinforces the desired behavior of the system appears to be better than a stronger technology that goes against the desired behavior of the system.
8. Understand the location and direction of reinforcement loops. By encouraging positive reinforcement feedback or changing the architecture of the system to include new positive reinforcement loops, it is possible to experience performance gains.
9. Make sure information is flowing. If information is not moving, or inadequate/incomplete information is being used, the system will not function or perform properly.

The conducted research was unique in nature in that it represents an action research approach that provides empirical evidence of how an OGD ecosystem of an entire country may be transformed. Furthermore, it documented and created a theoretically grounded framework based within action research so that the insights from this case could be applied and trialed elsewhere. The paper also demonstrated a process in which researchers can work together with the government, society, and private sector to enact systematic change within an OGD ecosystem and create public value. Future researchers, policy-makers, and those interested in OGD ecosystems may find this research useful for improving the performance of their own OGD ecosystems. Additionally, the paper provides some new insights into factors that appear to drive higher levels of performance when it comes to OGD ecosystems. As this paper presents the study of one ecosystem, that of Estonia, future research should be conducted to validate the initial arguments offered here. More empirical evidence about OGD ecosystems, their behavior, and their performance would be of high interest for the scholarly community. Furthermore, research that explores the existence of common or

similar feedback loops in different OGD ecosystems, and comparing the effects of these within their own context, could lead to new insights for the field and scholars of OGD.

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Table 1. OGD ecosystem characteristics in literature

Source	Ecosystem Characteristics
(Harrison et al., 2012)	Legal, Policy, and Economic Context; Government Policies and Practices; innovators: Technology, Business, and Government; Users, Civil Society, Business
(Lee, 2014)	Data audit, dataset selection, address and map data, data privacy, licensing, publishing high-quality data, data access, data discovery, supporting public bodies, engaging data users, encouraging economic reuse, evaluation
(Zuiderwijk et al., 2014)	Design, Context, Interdependencies and interaction, participants, data resources and tools
(Heimstädt et al., 2014a)	Data suppliers, intermediaries, data consumers, nested levels, cyclical, demand-driven, sustainable
(Immonen et al., 2014a)	Data providers, data brokers, service providers, application developers, infrastructure and tool providers, application users
(Dawes et al., 2016)	OGD beneficiaries, OGD Users, OGD Providers, Benefits, Community Characteristics, Data use & products, feedback & communication, Data publication, OGD Policies & strategies, Motivation for OGD development, Advocacy & interaction
(Kitsios et al., 2017)	Data providers, service providers, application users, application developers
(Styrin et al., 2017)	Policy, Society, Management

Table 2. Goals of the project "Promoting the Use of OGD"

Situation in 2017	Future Goals for 2018-2020	Relevant performance category
There are only 70 datasets on the OGD portal.	Every year for the procurement there should be at least 20 new OGD sets added to the portal.	OGD supply
The OGD portal is accessed only 800 times a month.	By December 2020, there should be an average of 2000 users of the OGD portal a month.	OGD usage
There are only four applications using OGD on the portal.	Every year for the procurement at least five new applications that use OGD should be added.	OGD usage
There is a public sector working group on OGD in Estonia, but it is no longer working.	The public sector working group on OGD in Estonia must meet at least three times a year.	Communication & interaction
There is an average of one OGD event a year.	Every year, starting from 2018, there should be at least three events related to OGD.	Communication & interaction
There are no news articles about OGD in the Estonian OGD portal.	Every year there should be at least six articles about OGD in Estonia in both English and Estonian.	Communication & interaction
There is no social media for raising awareness of OGD in Estonia.	By 2019 there should be a Facebook account for Estonian OGD with at least 1,000 likes.	Communication & interaction
Estonia has been covered in three international OGD rankings, but performs poorly.	The results of Estonia's OGD ranking should be improved by the end of the procurement, assuming the methodology of the rankings does not change.	All categories

Table 3. Data sources used for research

Data source	Time of data collection	Type of information obtained
Data collected during action research:		
Official government policy documents (Public Information Act, OGD Green Paper, Digital Agenda 2020, State Information Systems Interoperability Framework)	February-April 2018	Estonian OGD policy goals, formal regulations, requirements, expectations and restrictions pertaining to OGD
Direct participation of the researchers	February 2018-September 2019	Insider information on OGD-related activities and developments in Estonia; personal perceptions and reflections on the developments in the ecosystem
Meeting minutes from public sector OGD working group (5 meetings in total during the period) (15 to 20 attendees in each meeting)	February 2018-September 2019	Status of OGD provision and existing capabilities in public sector organizations; public sector stakeholders' perceptions on the barriers, challenges and needs regarding OGD supply and use
GitHub issue tracker history (https://github.com/okestonia/opendata-issue-tracker/issues, accessed 25.5.2020)	February 2018-September 2019	OGD-related issues and proposals raised by OGD stakeholders; dynamics of dialogue between stakeholders
Estonian official OGD portal and the issue and pull request history of the new portal's GitHub repository (https://github.com/okestonia/opendata.riik.ee, accessed 25.5.2020)	February 2018-September 2019	Statistics of published datasets and OGD applications; information on functionalities enabling interaction with data and between users
Monthly project team meetings (participation open to anyone interested) (average of 5 attendants)	March 2018-September 2019	Review of OGD-related issues and proposals raised by OGD stakeholders; project team's reflections on the progress
Project events and workshops (incl. 2 OGD forums with 100 participants and 1 technical stakeholder workshop with 30 participants)	February 2018-September 2019	OGD-related issues and proposals raised by OGD stakeholders; stakeholders' feedback to project activities and developments in the Estonian OGD landscape
Additional sources:		
Online survey of OGD experts and practitioners conducted as part of OpenGovIntelligence, an EU-funded project, in 6 European countries. The survey contained 11 open-ended questions on the perceived drivers and barriers of OGD supply and usage and yielded responses from 9 Estonian experts (out of 63 respondents in total)	May-June 2016	Experts' and practitioners' perceptions of OGD drivers, barriers, needs and opportunities in Estonia
Stakeholder co-creation workshop conducted by the researchers involved in this study as part of OpenGovIntelligence. The workshop was attended by seven public sector agencies and two private companies and followed the Nominal Group Technique method. The 1st session involved the discussion of problems and challenges to the creation of OGD-driven services and in the 2nd session user stories and personas were co-created for a selected pilot service.	September 2016	Public and private sector stakeholders' experience and views on OGD usage related problems and challenges in Estonia
Six personal semi-structured interviews with four public officials and two NGO representatives. The interview was based on five open questions on public service creation and OGD.	March 2017	Public sector and non-governmental stakeholders' perceptions on the opportunities and barriers regarding the usage of OGD in Estonia
International OGD indices: European Data Portal's Open Data Maturity Landscaping survey 2018 and 2019, OECD's Open Government Data Survey 3.0 and 4.0, an 4th edition of the Open Data Barometer	2017, 2018, 2019	External comparative evaluation of different dimensions of the OGD ecosystem (data provision, quality, usage, OGD policy, impact)

Figure 1. Five stages of action research. Source: Authors based on Baskerville (1997)

Figure 2. Agile and lean development process. Source: Authors

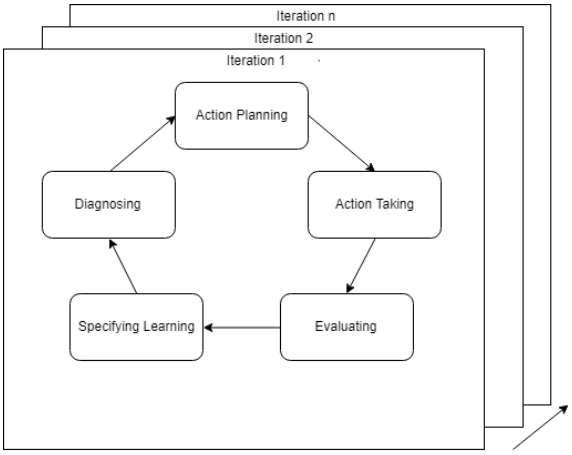
Iteration n
Iteration 2
Iteration 1
Action Planning
Diagnosing
Action Taking
Specifying Learning
Evaluating

Figure 1

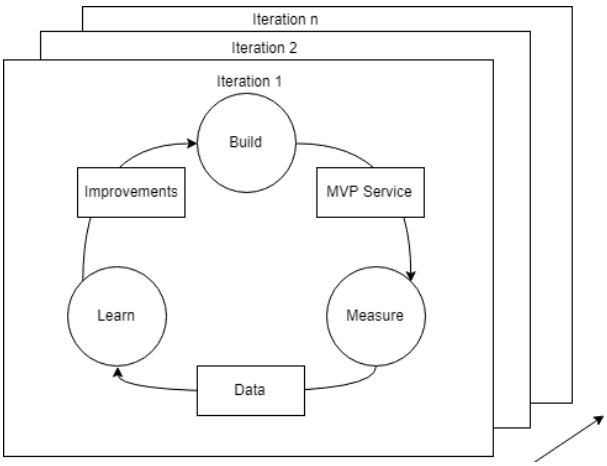

Figure 2